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AN ALGORITHM FOR CHLOROPHYLL USING FIRST DIFFERENCE TRANSFORMATIONS OF AVIRIS REFLECTANCE SPECTRA

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1. INTRODUCTION

Experimental results have shown the existence of a strong relationship between chlorophyll *a* concentration and remote sensing reflectance measured at lake level with a high resolution spectroradiometer (Melack and Gastil, 1994). The objective of our study was to investigate the relationship between surface chlorophyll *a* concentration at Mono Lake and water reflectance retrieved from Airborne Visible - Infrared Imaging Spectrometer (AVIRIS) data obtained on October 7, 1992. AVIRIS data were atmospherically corrected as described by Green et al. (1993). A description of the lake-level sampling is found in Melack and Gastil (1994). The relationship between chlorophyll concentration and both the single band reflectance and the first difference transformation of the reflectance spectra for the first 40 AVIRIS spectral bands (400 nm to 740 nm) was examined. The relationship was then used to produce a map of the surface chlorophyll distribution.

2. METHODS

The data were obtained on October 7, 1992. Two chlorophyll measurements were obtained at each of 20 stations. The AVIRIS reflectance signal was improved by averaging a 10 by 10 pixel window around each sampling station. These water reflectance measurements derived from AVIRIS do not include the correction for the skylight reflectance.

A first difference transformation of the reflectance spectra was performed:

$$D\lambda_i = (R\lambda_{i-g} - R\lambda_{i+g}) / \Delta\lambda$$

where $\mathbf{D}\lambda_i$ is the first difference transformation at band i, **g** is the gap, $\mathbf{R}\lambda_{i-g}$ is the water reflectance at the i-g waveband, $\mathbf{R}\lambda_{i+g}$ is the water reflectance at the i+g waveband and $\Delta\lambda$ is the center-to-center span in wavelength between the bands 2g apart. In this statistical analysis, two gaps were tested (gap=1 and gap=3). After the extraction of the reflectance spectra from the AVIRIS image cube and the computation of the first difference transformation with two different gaps, the three data sets were submitted to correlation analyses. The results of the correlation analyses were then used to select the best spectral bands for linear regression to measured chlorophyll.

3. RESULTS

The gap used in the computation of the first difference transformation strongly affected the results (Figure 1). The use of a three-band gap reduces the variance for all wavelengths and, as result, the correlation between the first derivative and the chlorophyll concentration. The highest r^2 between AVIRIS reflectance and chlorophyll are observed at 437 nm and 547 nm (Figure 2). These wavelengths correspond to the chlorophyll *a* absorption band in the blue region and to the minimum of the chlorophyll *a* absorption in the green band.

The correlation spectrum derived from the AVIRIS reflectance spectra differs from the correlation spectrum computed by Melack and Gastil (1994) using the field spectra measured on four different dates (44 samples) covering a chlorophyll range of 0.9 μg/l to 47.7 μg/l. The correlation spectrum in that case showed very low correlation between chlorophyll concentration and reflectance in the green region. The highest correlation ($r^2 > 0.80$) was located in the blue region and in the red/near-infrared region.

The AVIRIS reflectance is less correlated to chlorophyll concentration ($r^2 < 0.60$) than the first difference using either gap. The slope between adjacent bands of the reflectance spectrum better predicts chlorophyll than the reflectance brightness at a single band. The first difference transform with a gap of one band provided better results than a gap of three bands. The highest values are found from 540 to 580 nm. In the blue region no high correlation was observed. The improvement in the relationship between chlorophyll concentration and remotely sensed data by using the first difference of the reflectance spectra can be explained by the low water-leaving radiance that makes it difficult for AVIRIS to detect changes in the amount of reflected energy in single wavebands.

On the basis of the previous results, the first derivative at 557 nm was selected for computing the regression model to estimate the chlorophyll concentration (Figure 3). The statistical performance of the model is excellent, producing a standard error for the residuals equivalent to 2% of the average chlorophyll concentration ($t=7.09$, $F=50.3$, $p<0.0001$, $r^2=0.74$, rms=1.5 μg/l). The average difference between the measured and predicted surface chlorophyll concentration is 0.33 μg/l.

The regression model was used to derive a chlorophyll map of Mono Lake showing the spatial distribution of the surface chlorophyll concentration.

4. CONCLUSIONS

The results presented in this report show that first difference of AVIRIS spectral reflectance can be used to estimate chlorophyll concentration in eutrophic lakes. The best model performance for data collected at Mono Lake on October 7 1992 was obtained with the 557 nm band. This approach should be tested for different dates and for different ranges of concentration in order to assess how much the present model is affected by the optical conditions of the lake.

5. REFERENCES

Green, R.O., J.E. Conel, D.A. Roberts, "Estimation of aerosol optical depth, pressure elevation, water vapor, and calculation of apparent surface reflectance from radiance measured by the airborne visible/infrared imaging spectrometer (AVIRIS) using a radiative transfer code", **SPIE**, Imaging Spectrometry of the Terrestrial Environment, Vol 1937, p 2-11, 1993

Melack, J.M., M. Gastil, "Comparison of spectral feature algorithms for remote sensing of chlorophyll in eutrophic lakes", **IGARSS 94,** 1994.

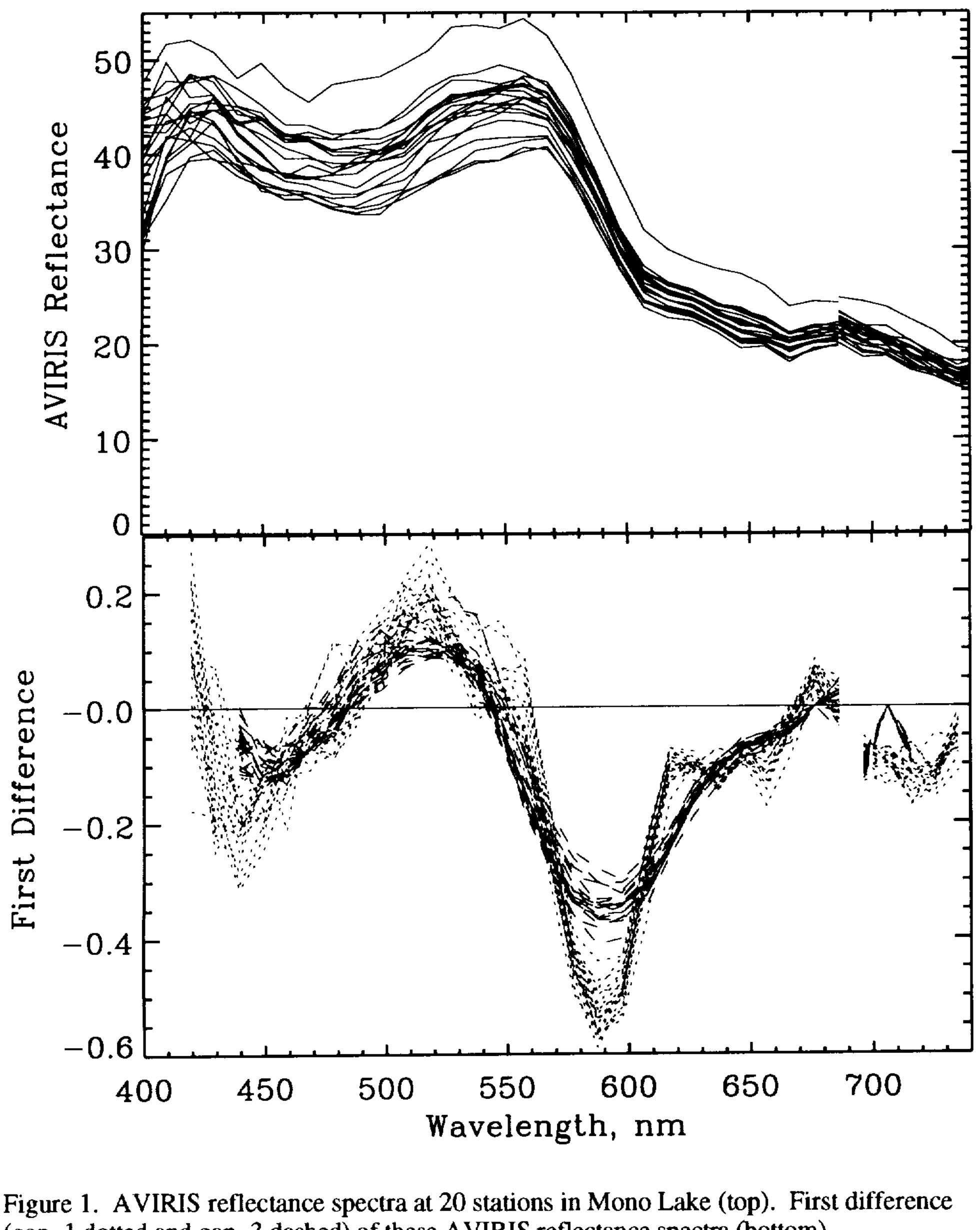

Figure 1. AVIRIS reflectance spectra at 20 stations in Mono Lake (top). First difference (gap=1 dotted and gap=3 dashed) of these AVIRIS reflectance spectra (bottom).

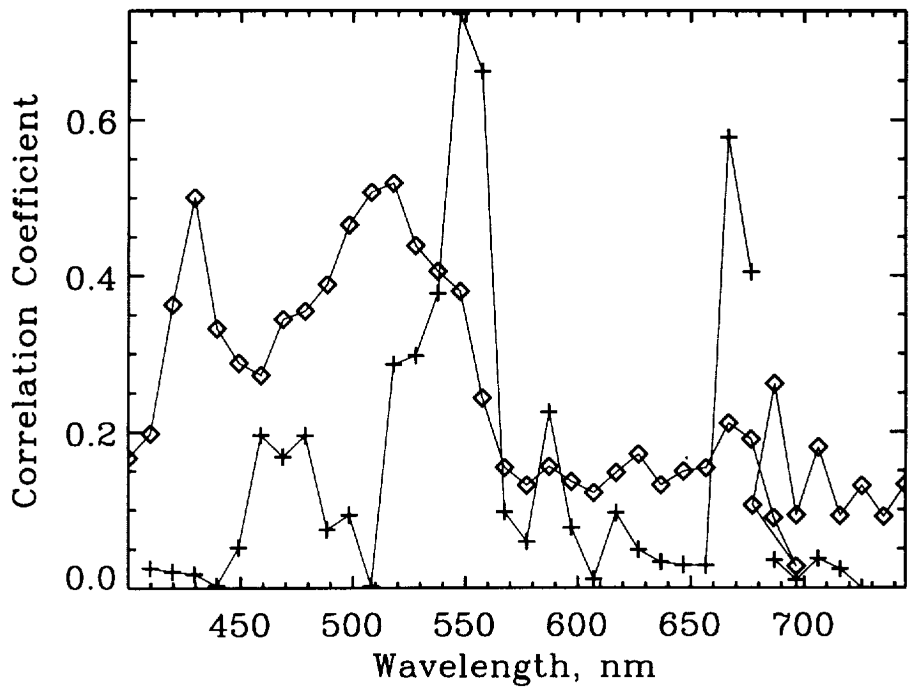

Figure 2. Spectral variation of the r^2 for the AVIRIS reflectance at single bands (◊) and first difference of the AVIRIS reflectance with gap 1 (+).

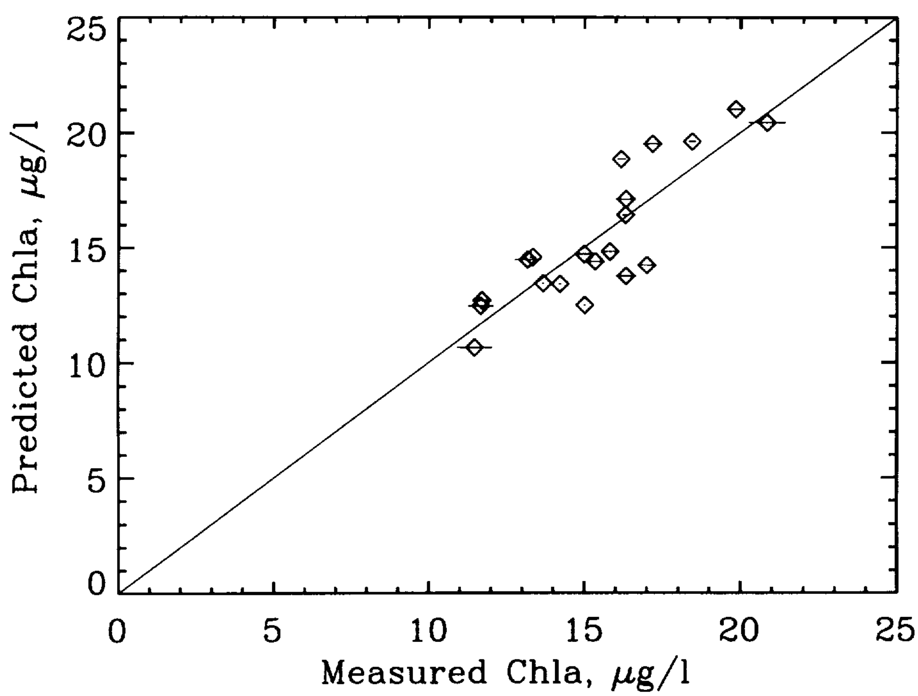

Figure 3. Predicted versus measured chlorophyll concentration. The horizontal bars show the range of two measurements at each of the 20 stations.